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A STUDY OF THE NUCLEAR SCALING PHENOMENON AT HIGH ENERGIES

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ABSTRACT

We propose to investigate the phenomenon of nuclear scaling by studying the interaction of high energy protons with nuclei. By measuring the inclusive momentum and angular spectra of the particles emitted backward in the laboratory system we will gain an understanding of the nuclear scaling mechanism.

We will measure the spectra of backward particles with momentum $p > 300$ MeV/c in the angular range from 90° to 175°. We intend to work with different nuclear targets to study the A-dependence of the phenomenon.

I. Introduction

We propose to investigate the phenomenon of nuclear scaling by studying the interaction of high energy protons with nuclei. By measuring the inclusive momentum and angular spectra of the particles emitted backward in the laboratory system we will gain an understanding of the nuclear scaling mechanism. The phenomenon of the nuclear scaling was discovered in 1973 and is being studied now in many laboratories at low energies. For the proposed experiment we will make use of existing equipment and we hope to complete the work in a short time.

II. Physics Motivation

After the discovery of nuclear scaling the existence of the phenomenon was confirmed by several experiments performed over the last few years.[8]

The essence of this phenomenon is as follows:
In the deep inelastic nuclear reactions, such as:

$$a + A \rightarrow b + \text{anything} \tag{1}$$

where a - incident particle

A - nuclear target

b - baryon (p, d, t...)

the inclusive spectrum of particle b is given by the invariant function

$$\rho = \frac{1}{\sigma} \cdot \frac{E}{p^2} \cdot \frac{d^2\sigma}{dpd\Omega} = C\, e^{-\frac{T}{T_o}} \simeq C\, e^{-Bp^2} \tag{2}$$

where σ is the (a, A) inelastic cross section

and E, p, T are the total energy, momentum and kinetic energy of particle b.

The main features of the invariant function (2) are:

1) The parameter T_o which characterizes the spectrum slope is independent of the energy and independent of the type of incident particle,

$$T_o \neq T_o\ (E_a, a),$$

and T_o is also independent of the mass number of the target,

$$T_o \neq T_o\ (A)$$

for energies above some critical energy ~ 1 GeV.

2) The parameter C is also independent of both the energy and the type of incident particle

$$C \neq C\ (E_a, a)$$

for energies above some critical energy depending on the mass number of the nucleus A.

3) The spectrum of particle b does not depend on the characteristics of the leading particle, i.e., there is a factorization of the process.

4) The variable C is a function of mass number of the nuclear target

$$C \sim A^{2/3}$$

5) The parameters C and T_o do depend on the type and the emission angle of particle b.

Figures 1 through 3 show, for example, some experimental results which confirm the above mentioned features of the invariant function. Figure 1 shows the coefficient B as a function of initial energy for proton emission angles in the range:

$$120^o < \theta_{1ab} < 150^o$$

This figure taken from reference[8] presents the results of studying the reaction (1) with different incident particles (protons, pions, gammas). Let us note that the point marked by a star is a preliminary result of the measurement of the parameter B in $\bar{\nu}$ Ne interactions at Fermilab (Experiment 180).

The difference of the parameter B for the different nuclei as a function of the momentum of particle a is shown in Fig. 2. Finally, Fig. 3 shows the variation of (σ_p/σ_T), which is proportional to the parameter C, as a function of initial energy for different nuclei. One can see in Fig. 3 that the critical energy increases with increasing mass number and that above some critical energy the C parameter is a constant.

We can consider the above features of the invariant function (2) as being due to the limited fragmentation of the target. The relations (3-5) are valid in the asymptotic region.

There is a deep analogy between the phenomenon of nuclear scaling and the phenomenon of target fragmentation in the case of elementary particle interactions. Apparently, these common features originate from the fact that a nucleus and an elementary particle are composite systems of strongly interacting particles. It is very interesting to investigate the mechanism of the nuclear scaling phenomenon and especially the details which are related to the case of elementary particle interactions.

At the present time there is no generally accepted theory of nuclear scaling. Moreover, there is no theory which describes all the main features of the phenomenon. It is worth mentioning the following models: the local heating model[2], the representation of a nucleus as a quark bag[3], the multiperepherical model for nuclear interactions[4], the multiple scattering model[5], and the model which considers the existence of fluctuons in nuclei[7], (see also reference 8).

Let us note that the investigation of reaction (1) in some sense is equivalent to experiments on the interactions of fast ions with nuclei. It is true if there is a factorization of the process, as is shown in reference 6.

It would be interesting to check the relations (3-5) at the highest available energy because these relations are predicted to be valid in the asymptotic region. This is why we propose to measure the spectra of backward positive particles at the energies of the Fermilab accelerator.

III. Apparatus

We propose to use for this experiment the now existent one-arm spectrometer which was used by experiment 284. The characteristics of this apparatus are adequate to our task. This spectrometer provides the opportunity to measure the spectra of low momentum particles from 0.3 GeV/c up to 2.5 GeV/c in the angular range up to 175^{o}. The secondary particles will be reliably identified using Cerenkov counters and the time of flight method.

We propose to measure the momentum spectra of particles in the region 300-1000 MeV/c. The lower limit of the spectrum is determined by the absorption of the secondary particles in the target and in the scintillators. The upper limit is defined by statistics. The event rate decreases very drastically with increasing momentum of the secondary particles. In order to check the relation (2) we expect that it will be sufficient to measure total momentum spectrum (up to 1300 MeV/c) using only 1 or possibly 2 different nuclear targets, for example, Cu and Pb. As usual a low event rate requires special measures for background suppression. For this purpose a vacuum must be provided on the whole path of the incident beam. The nuclear target must also be in a vacuum tank.

To measure the angular dependence of the coefficient B we intend to measure the momentum spectra for 5 different angles of secondary particle emission.

We propose to use the following different nuclear targets to study the A-dependence: Be, C, Al, Cd, Cu, and Pb. The different targets of thickness 0.5 g/cm^2 will be mounted on a rotating wheel to make possible fast changes of the target during a run.

A monitor target will be mounted ~ 5m downstream of the main target. The relative calibration will be done using a 90° scintillator telescope. The absolute calibration will be done using a radioactivity method.

We request approximately 100 hours for a test run and approximately 150 hours for the main run with intensity about $2 \cdot 10^{11}$ ppp. The statistical accuracy of the determination of the coefficient B will be ~ 3%. This accuracy is of the same order or better than the accuracy of the determination of the coefficient B in present experiments.

REFERENCES

[1] Y. D. Bayukov, et al., The International Seminar on Deep Inelastic and Many-body Processes at High Energies. Dubna, 472 (1973).

[2] A. M. Baldin, 'Kratkie soobshenia po Physike AN USSR', 1, 35 (1971).

[3] A. V. Efremov, Yad. Fiz, 24, 1208 (1976).

[4] Y. D. Bayukov, et al., Yad. Fiz., 18, 1246, (1973).

[5] V. B. Copeliovitsh, Pisma v GETF", 23, 348 (1976).

[6] D. E. Greiner, et al., Phys. Rev. Lett., 35, 152 (1975).

[7] V. V. Burov et al., Preprint JINR, Dubna, E2-10680 (1977).

[8] G. A. Leksin, XVIII International Conference on High Energy Physics, Tbilisi (1976).

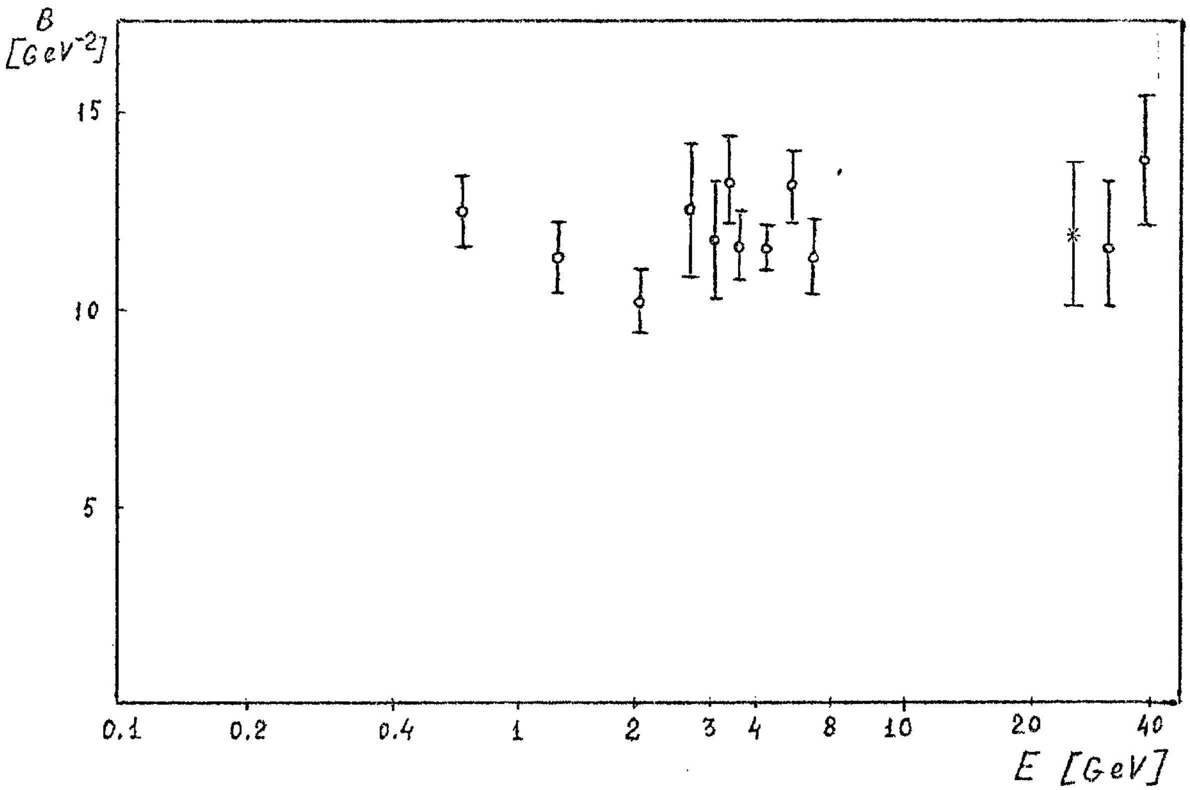

Fig. 1

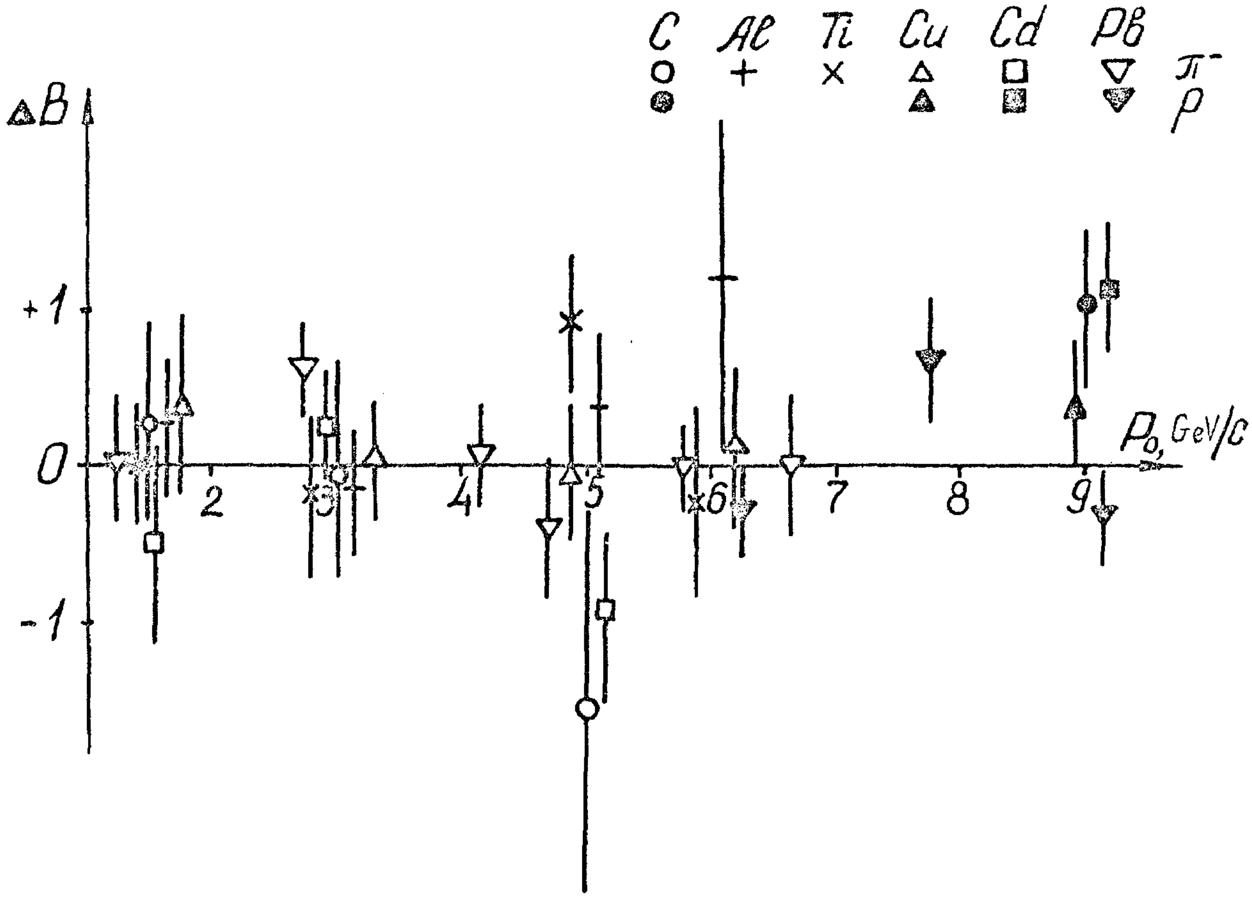

Fig. 2

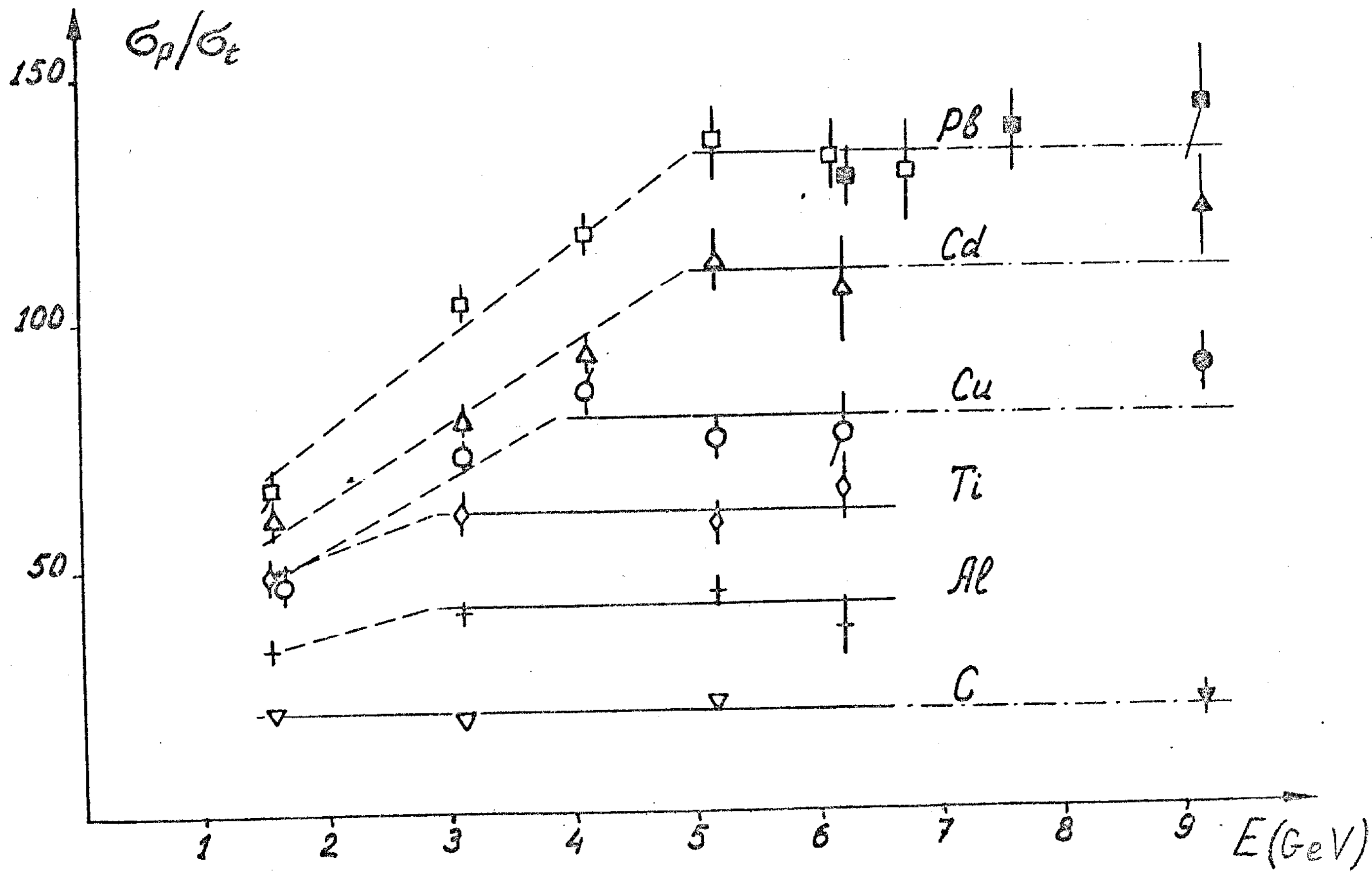

Fig. 3